

## Background and Research Prospect of Geo-ecological Survey and Monitor in the Critical Zone of Black Soil



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The American Science journal, on the occasion of its 125 publication anniversary, in 2016, released 125 of the most challenging scientific issues (Kennedy et al., 2005) to the world. According to the basics, breadth and the influence, 25 of the issues which considered to be the most important were screened, including “How many people can the Earth carry?” (Stokstad, 2005; Dailyg et al., 1992; Cohen, 1995) and “How high will the greenhouse effect make the earth temperature?” These two scientific problems are based on resources and the environment: the population limit that the earth can carry is related with the land and surface water resources and ecological environment carrying capacity; the root of the greenhouse effect is the increase of CO<sub>2</sub> in the atmosphere, and the soil is the largest carbon bank in the terrestrial ecosystem, the impact of soil resources on the greenhouse effect can not be ignored. Traditional soil resources are only problems related to agriculture or human food and clothing and can no longer fully reflect the overall function and value of the soil. The soil not only provides food and fibre for human beings, but has social, ecological, economic, cultural and spiritual dimensions (Robinson et al., 2012). It also plays an irreplaceable role in ensuring environmental safety and energy security, documenting the evolutionary history of the earth and humanity, and protecting biodiversity, and the soil is at the heart of safeguarding the structure and function of the Earth’s ecosystems.

### 1 Overview of black soil resources

There are only four black soils in the world, all developed in the mid-latitudes, in Northeast China, North America, Ukraine to Southern Russia and South America’s Pampas, with a total area of about 916 million hectares, accounting for about 7% of the world’s frozen soil. The three black soils of the northern hemisphere are mainly distributed in the middle and low latitudes at the core of the North 46° belt (Fig. 1); The black soil region of North America straddles southern Canada, the central

plains of the United States and northern Mexico, About 290 million hectares; the black soil region of Eurasia began in the sub-humid grasslands of south-central Europe, extending intermittently to Russia and northeastern China, about 450 million hectares; and the black soil region of South America is mainly located in Argentina and Uruguay, about 102 million hectares.

### 2 Proposal of the concept of black soil critical zone

The earth system is an organic whole composed of the atmosphere, hydrosphere, continental circle (crust, mantle, core), and a biosphere (including humans). Earth System Science is the emergence of the fundamental living environment crisis facing mankind—the severe challenge of global change, the study of the composition of the earth system subsystem between the interconnection, the mechanism of interaction, the law of changes in the earth system and the mechanism to control these changes, so as to establish a scientific basis for global environmental change prediction, and for the scientific management of the earth system to provide a basis. According to the content of earth system scientific research, a scientific concept is needed to express the research object in earth system science. Since 2001, the National Research Council of the United States, the National Science Foundation of the United States, the Pennsylvania State University Susan Brantley, Lin and others have made different representations of the areas covered by the Earth’s critical zone (Brantley et al., 2005; Lin et al., 2005; Lin, 2010), pointing out that the earth’s critical zone is a complex, interdependent, network “focus” areas composed of geological, geochemical, biological, hydrological, geomorphological and atmospheric processes, with spatial boundaries ranging from the vegetation canopy to the bottom of the groundwater aquifer, containing the near-surface biosphere, the atmosphere, the entire soil circle, as well as the hydrosphere and lithosphere surface/near surface parts. Matson first summed up the connotations of soil circles in 1938 and pointed out that soil is the product of the

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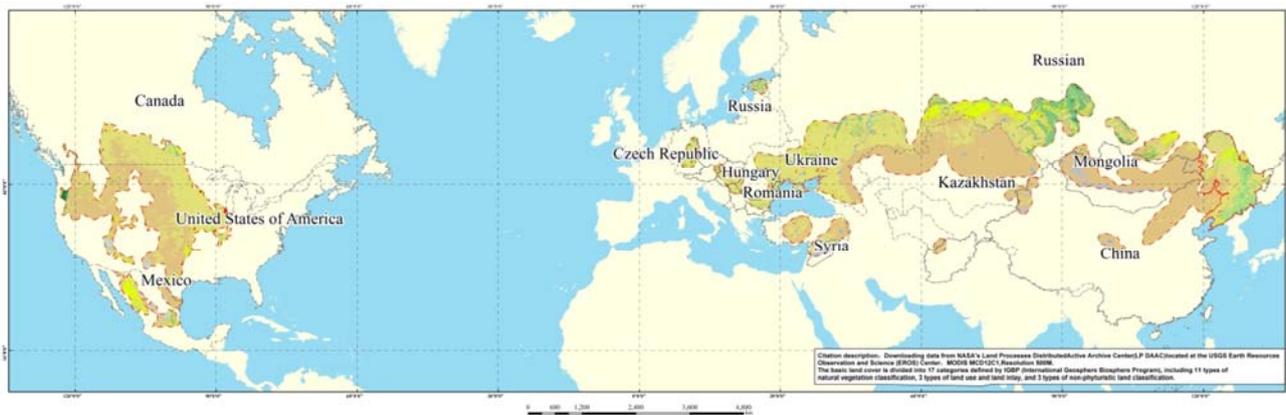


Fig. 1. Distribution of black soil resources in north latitude 46 degrees and land use status in 2016.

interaction of lithosphere, hydrosphere, biosphere and atmospheric circles (Mattson et al., 1938). In the 80-90 years of the 20th century, Chinese scientists further enriched the connotation of the soil circle, believing that the soil circle is a continuum or overlay composed of soil covering the earth's surface and the bottom of the shallow water area, which is similar to the biofilm of the organism to some extent. Compared to other circles of the earth's surface system, the soil ring is not only the most active circle of the earth's surface system, but also the relatively stable and susceptible to human activities of the ring layer, at different time scales to reflect and record the climate, biological and human activities caused by environmental changes (Lin H, 2010), is the geosphere system connected to the atmosphere, the core elements of the hydrosphere, Biosphere and lithosphere (Zhao, 1991, 1994, 1997, 2015). Black soil, because of its rich organic matter and fertile soil, has an important contribution to agriculture and animal husbandry in various countries, is an important guarantee area of world food security, and is also a common resource for the global and all mankind. Under the background of the escalation of Sino-US trade disputes, the importance of black soil in northeast China in safeguarding the country's food and food safety is highlighted. However, after more than hundreds of years of reclamation, especially in recent decades, the black soil is facing serious degradation problems, such as soil erosion, salinization and soil pollution.

## 2.1 Status of investigation, research and monitoring of black soil

From different fields such as earth's critical zone, global climate change, basic background environment, agriculture and soil resources environment, the black soil distribution area is found in many kinds of investigation and research work. Since 1988, nearly 30 countries around the world have jointly implemented the IGCP 259 International geochemical Mapping Programme and the IGCP360 Global geochemical baseline plan, establishing the earth's critical zone geochemical Observation Network (2000 monitoring sites), Continuous recording of chemical elements in the lithosphere-soil circle-hydrosphere-atmosphere between the circulation and changes, for global environmental change, model building and human activities to provide a large number of empirical data, the geochemical responses of biological extinction, paleoclimatic change and major geological events were studied by using reference values and the sensitive response characteristics of chemical elements. In 1997, the United States Treasury and the Ministry of Agriculture collaborated in the launch of the Mississippi Carbon Cycle programme, which provides systematic observation studies on the effects of land use, weathering, sedimentation and

soil formation on carbon banks and nutrient circulation in the basin. In 2007, David Smith and the United States Land Authority carried out soil geochemical and mineralogical studies of low density (1 points/1600 sq km) of soil geochemical landscapes. Since 2003, the China Geological Survey has organized a national multi-target regional geochemical survey, completed nearly 450,000 square kilometers of soil geochemical survey in the north-east black soil distribution area, and made a systematic evaluation of soil nutrients and soil environmental conditions. In 2009, the global geochemical benchmark IUGS commission (Alecios Demetriades, clemens, Manfred Birke) implemented three geochemical survey projects, namely, European FOREGS geochemical atlas, European Union surface water geochemistry and GEMAS agro-pastoral soil, and in 2014 released high-quality and comparable geochemical data on agricultural land use soils, as well as European soil parameters on the toxicity and biological absorptivity of metallic elements. In the 2006-2014, the American Science Foundation established 10 earth-critical zone observatories to conduct research on the surface processes, the environment and the maintenance of life on earth's critical zone. The European Commission SoilTrEC Project has established a watershed scale calculation process model for soil erosion, solute transport, nutrient, carbon conversion and food chain integration. A number of French scientific institutions have jointly established a network of French river basins to monitor the permanent environment on the earth's surface, study the cycle of surface water and chemical substances, and understand the response of the earth's key bands to forced changes from short-term climate change to long-term climate change, based on land cover and soil state studies. Germany established the earth critical zone observation network platform to address the impact mechanisms of climate change on terrestrial (including groundwater, soil, vegetation, surface water), feedback on surface system exchange processes (such as surface and atmospheric feedback) on the surface flux of water and other substances, changes in soil and land use patterns to water balance, a wide range of anthropogenic disturbances, such as soil fertility, biodiversity and regional climate impacts, mining and deforestation, can have an impact on terrestrial systems. At the same time, countries in the black soil organic carbon, nitrogen, phosphorus and potassium and other spatial and temporal changes, black soil and water loss and other degradation problems have done a lot of research (Yuet al., 2004; Li et al., 2008; Yu et al., 2009; Xie et al., 2008; Wang et al., 2002, 2007).

With the development of remote sensing technology, remote sensing and spectroscopy are used to characterize the global soil (Mulder et al., 2011; Malley et al., 2004; Schlesinger, 1977; Swayze et al., 2000; Swayze et al., 2006; Viscarra Rossel et al.,

2006, 2011, 2016; Vasques et al., 2014; Fabrício et al., 2015). Dr. Veronika Kopaková (Veronika, 2014, 2017) launched the “Earth observation-land degradation and environmental monitoring” of the programme of activities of the -GEO Commission on International Initiatives (CA), using the same standards and norms to establish mineral/soil spectral banks and establishing spectral data with clear geochemical definitions that can represent soil in different European countries. In the 2016, Australian scholars developed and analyzed the global soil visible-near-infrared spectroscopy database, which can describe soil composition based on land use and geological background, and can predict soil organic carbon, inorganic carbon, clay, fine sand, gravel, sand and iron content, cationic exchange energy and PH value.

## 2.2 Problems in the study of black soil land

Judging from the current research status of soil and earth critical zone, United States, Europe and other developed countries, as well as China, have carried out multi-disciplinary cross-correlation research on the earth's critical zone from soil circles, hydrosphere and atmosphere, but the surface/near surface part of the global black soil distribution area as part of the independent individual or the earth's critical zone, the investigation and research specific to the black soil distribution area lack of systematization, the content of the investigation is occasionally overlapping, the interdisciplinary intersection is few, the methods of investigation method are limited, the black soil and its related water, biology, vegetation, atmosphere and other multidisciplinary cross-systematic geological ecology survey are not carried out, and the corresponding theoretical methods and technical system have not been formed.

## 2.3 The concept of black soil critical zone

Black soil is the most valuable soil resources on the earth, with unique geographical distribution characteristics, which is different from the Chinese loess formed in the dry heat environment and the southern red clay formed under the hot and humid environment. The northeast black soil at the northern edge of the East Asian summer monsoon is formed in a relatively wet and cold environment, the black soil ability of organic matter and aggregates, black soil affects the overall kinetic mechanism of hydrosphere, atmosphere and biosphere, and the study of soil resources and changes is an important part of earth's critical zone research according to the relationship between soil circle and other circles and the concept of earth critical zone. Therefore, the “critical zone of the black soil” and “geological and ecological investigation and monitoring of the critical zone of the black soil in the world” are put forward. The critical zone of black soil refers to the black soil distribution area between northeast China to west Russia-Ukraine and the 40-50° of the Mississippi R. basin in the United States, which is distributed in the core of 46 degrees north latitude, and includes not only weathered loose layers, but also vegetation, rivers, lakes and so on. The longitudinal space boundary passes from the upper boundary plant canopy down to the ground surface, the soil layer, the unsaturated aerated zone, the saturated aquifer, the near-surface biosphere, the atmosphere, the entire soil circle, and the surface/near surface portion of the hydrosphere. The critical zone of black soil has relatively independent special attributes and is also an important part of the critical zone of the earth. The research on the Geological Ecology Survey and monitoring of black soil under the perspective and framework of earth system Science is called the Geological Ecology Survey (BASGES) of the critical zone of black soil.

## 3 Several major scientific issues and future research content

Under the framework of scientific research on earth critical

zone, the formation of black soil, evolution as the main line, carries out the multi-disciplinary comprehensive investigation and monitoring of the land-water-atmosphere-biological multi-circle layer in the critical zone of the black soil, and solves the major scientific problems existing in the critical zone of the black soil. The future research direction and content mainly include:

(1) Study of black soil formation ERA and paleoclimatic environment: through fine chronology (including  $^{210}\text{Pb}$ ,  $^{137}\text{Cs}$ , photoluminescence, AMS  $^{14}\text{C}$  and other reliable dating methods for young sediments), geochemical analysis of constants, trace and rare earth elements, U-Pb analysis, etc., to determine the era of black soil formation in northeast China, material composition, temporal and spatial changes and differences, through sporopollen, biological fossil analysis and so on to extract independent and reliable paleoclimatic and ancient environmental indicators (such as the current in loess and various types of continental sedimentary mature environmental magnetism, organic geochemistry, ancient ecological indicators, etc.), the establishment of the northeast black soil paleoclimatic and environmental evolution of the time series, identify important climatic and environmental events in geological history, realize the reconstruction of ancient temperature and ancient rainfall in northeast China based on black soil in the past tens of thousands of years, and find out the temporal and spatial manifestation and evolution characteristics of the ancient climate represented by the critical zone of black soil.

(2) The quantification of soil structure, the material composition of black soil and the expression of its quantitative parameters, the study of the source and material components of dark soil mainly include the geochemical analysis of Common, trace and rare earth elements, the analysis of U-Pb, etc.

(3) How soil function in black soil area responds to land use, erosion and other human disturbances, the release and absorption of soil carbon in the process of land use and its impact on and response to climate change.

(4) The spatial and temporal variation law and main control factors of the migration and transformation of the water-black soil nutrient-pollutant in the critical zone of dark land are mainly the migration law of nutrients, water and pollution elements in black soil since the reclamation of black soil and the industrial revolution, the pollution status (especially heavy metals such as mercury and lead), the history of pollution.

(5) Global climate change and the formation and evolution of black soil in human activities, the black soil carbon cycle and its relationship with climate change, human activities.

(6) Comprehensive research on black soil area mapping, monitoring and modeling. Based on the theory of black soil formation and evolution, one is to use sensor technology and measurement technology to carry out point monitoring on the micro scale; the other is to use remote sensing technology to carry out large-area monitoring on the macroscopic scale, establish key belt observation stations integrating remote sensing, geochemistry, hydrogeology and other disciplines, and use multi-scale data and key belt observation data integration model to observe and predict the changes and future trends of key belt of black soil.

**Key words:** black soils resource; black soil critical zone, earth critical zone

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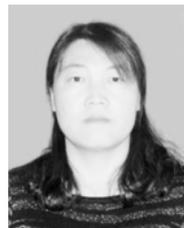
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